Generation 5 Batteries for Mobility:

Advancing Europe's Post-Lithium Energy Future

HighMag

ANGeLiC

TALISSMAN

Andréia Santos
Senior Innovation Project Manager
F6S Innovation

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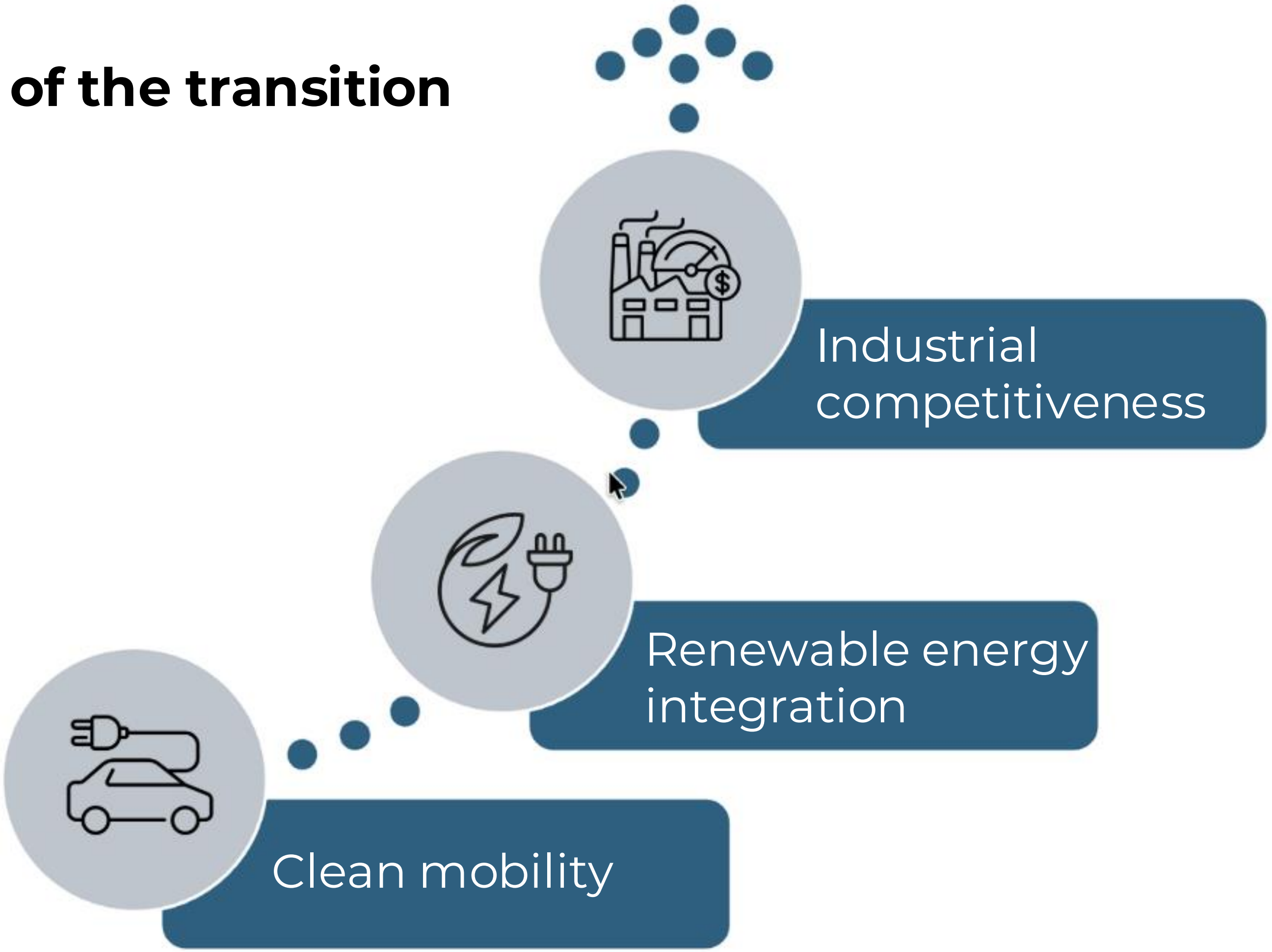
Why this matters?

Batteries at the core of the transition



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Why go beyond Lithium-Ion batteries?

Lithium-Ion

- Limits in energy density
- Cost pressures
- Sustainability concerns
- Critical raw materials dependency

Gen-5

- Higher Energy Density
- Faster Charging
- Improved Safety and Sustainability
- Longer Lifespan
- Cost Potential

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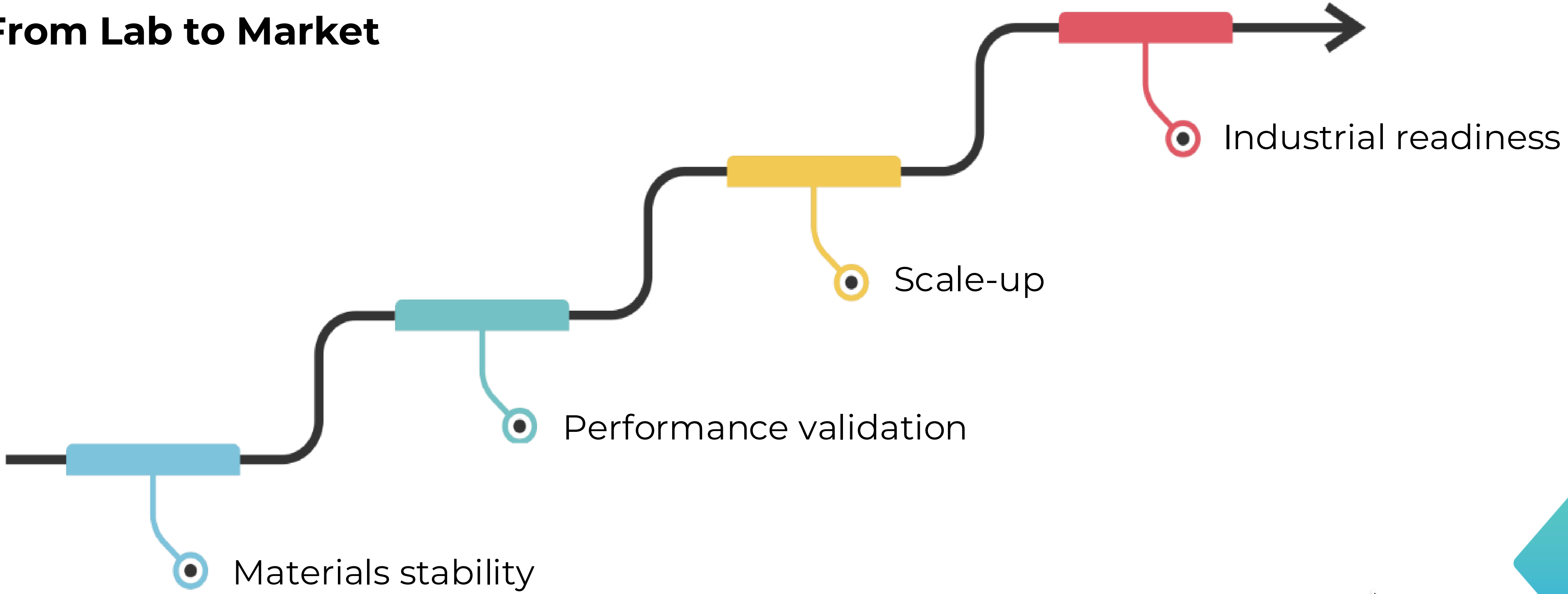
Generation 5 Batteries - Key Challenges

From Lab to Market



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EU Strategic Context

European Collaboration Matters

- Horizon Europe
  - *HORIZON-CL5-2024-D2-02-02 Post-Li-ion technologies and relevant manufacturing techniques for mobility applications (Generation 5)*
- *Cross-sectoral solutions* for the climate transition
- Stronger EU battery ecosystem
- Support long-term strategic goals.

ANGeLiC

Next Generation Lithium-Sulphur Battery Cell

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Magnesium-Based Technologies

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Safe and Sustainable Advanced Lithium -Sulphur Batteries

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Webinar Agenda

Project Presentations

ANGeLiC: ALD-Protected Li-S: The ANGeLiC Approach - ***Dr. Markéta Zukalová***

HighMag: Magnesium batteries as a key technology for a sustainable energy future - ***Dr. Yuri Surace***

TALISSMAN: Lithium–Sulfur Batteries: Powering the Future of Safe and Sustainable Mobility - ***Dr. Ainhoa Fernandez***

Challenge Blocks

Challenge Block 1 - Materials & Technology Breakthroughs - ***Dr. Damian Cupid***

Challenge Block 2 - Manufacturing & Industrialisation Readiness - ***Dr. Didier Devaux***

Challenge Block 3 - Gen 5 for high energy and high-power applications - ***Dr. Christian Jordy***

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ALD-Protected Li-S: The ANGeLiC Approach

Dr. Markéta Zukalová

J. Heyrovsky Institute of Physical Chemistry

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ALD-protected Next Generation Lithium-Sulphur Battery Cell

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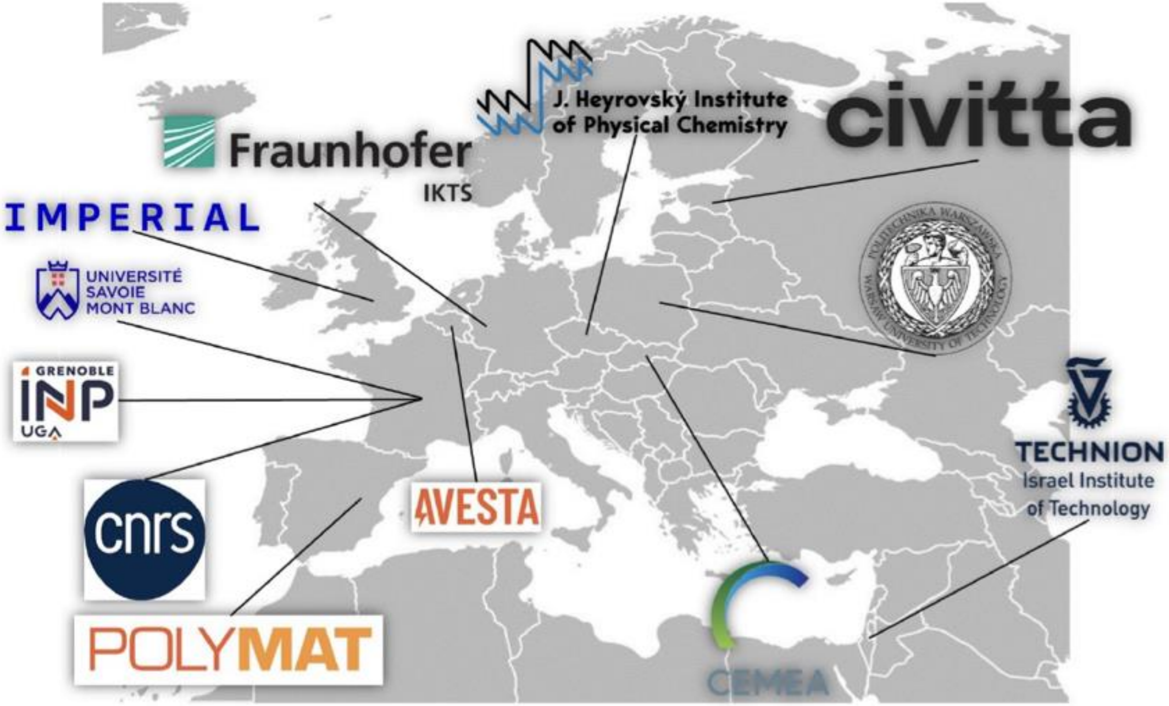
ANGeLiC

Advancing Next-Generation Lithium–Sulphur Batteries for Europe's Post Li-ion Future



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Vision & Positioning

EUROPEAN BATTERY FUTURE

⬆

ANGeLiC PROJECT
Interface-Engineered Li–S

⬆ ⬆ ⬆

Advanced Interfaces (ALD/MLD coatings) | Li–S Chemistry (High energy) | Scalable Manufacturing (Li-ion compatible)

⬇ Stability | ⬇ Performance | ⬇ Industrialization

BEYOND Li-ion BATTERIES

Aligned with Battery2030+ roadmap
High energy density, safety, and cost advantage

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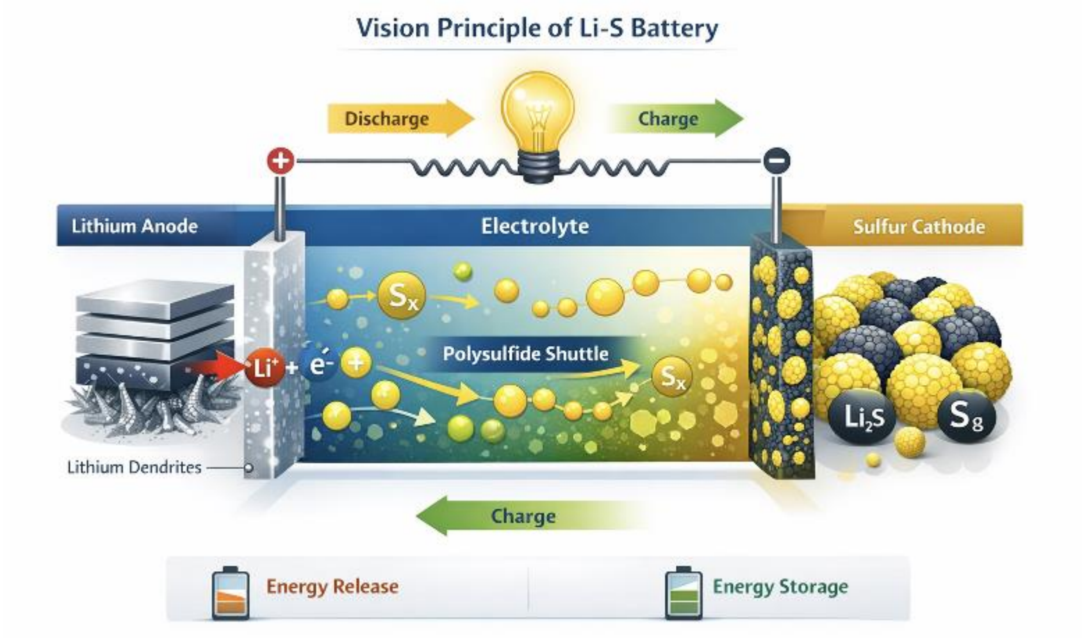
ANGeLiC

Core Technological Approach



Theoretical capacity1675 mAh/g

- ALD/MLD coatings for interface control
- Lithium metal anode protection
- Sulphur-carbon cathode stabilization
- Operando diagnostics

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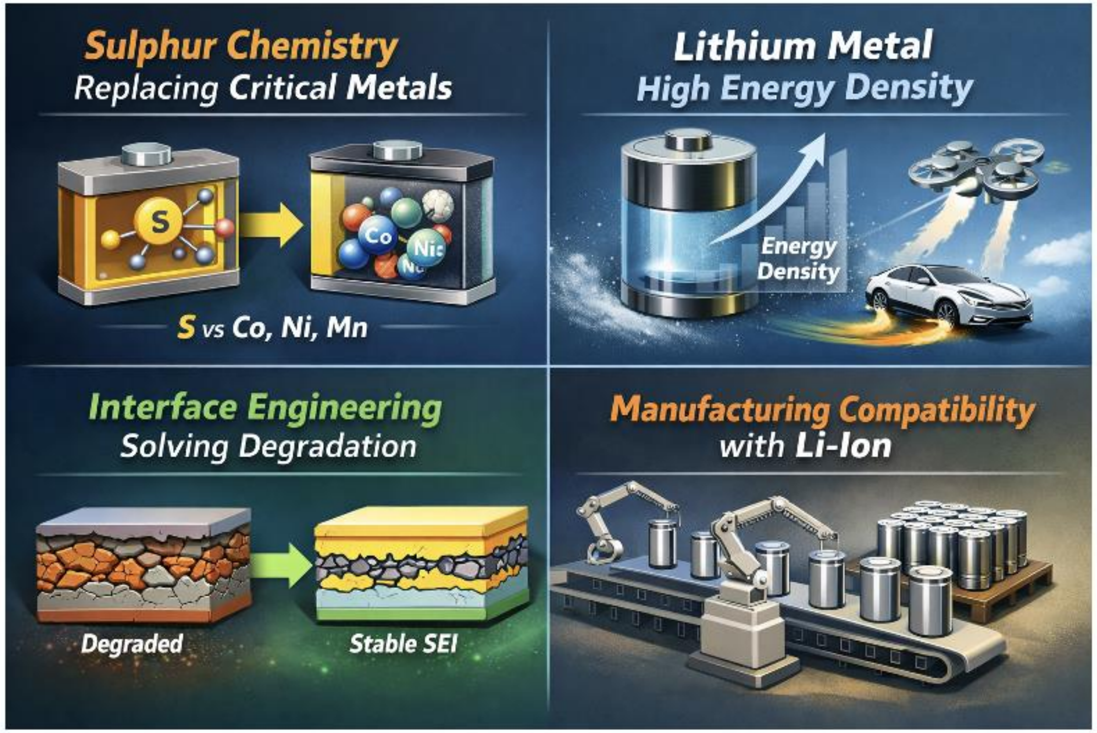
Key Innovation vs Li-ion



- Sulphur chemistry replacing critical metals
- Lithium metal enabling step-change energy density
- Interface engineering solving degradation
- Manufacturing compatibility with Li-ion

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Addressing key Li-S battery limitations

Challenge 1: Anode degradation

ANGeLiC solution: Multiple complementary protection layers

- ALD/MLD ultra-thin coatings (precision nanoscale control)
- Polymer electrolyte application (mechanical stability)
- Electrolyte additives (engineered SEI formation)

Challenge 2: Cathode shuttle effect

ANGeLiC solution: Multi-mechanism stabilization

- Macro-porous carbon matrices (physical trapping)
- Protective ALD coatings (barrier layers)
- High-entropy electrocatalysts (accelerated conversion)
- Advanced binders (chemical coordination)
- Optimized electrolyte compositions (fluorine-free salts and additives to reduce polysulfide solubility)

Challenge 3: Electrolyte limitations

ANGeLiC solution: Dual-track development

- Liquid: Fluorine-free salts
- Polymer: Hybrid formulations with ionic liquids

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Targeted Performance Ambitions/2030 Pathway

- *Ultra-thin* Li deposition (10-30 μm) + *high-capacity* sulphur cathode + optimized cell design
    - Higher energy density vs Li-ion
    - 500Wh/kg, 600Wh/l
- *Prevented shuttle effect* + stable SEI formation + protected cathode
    - Improved cycle life trajectory
    - 800+ cycles at 50% DoD
- Multi-layer *anode protection* + polymer electrolytes + real-time *sensor monitoring*
    - Enhanced intrinsic safety
- Abundant materials (*sulphur*) + *scalable R2R manufacturing* + reduced material usage
    - Cost reduction potential
    - < 75 EUR/kWh

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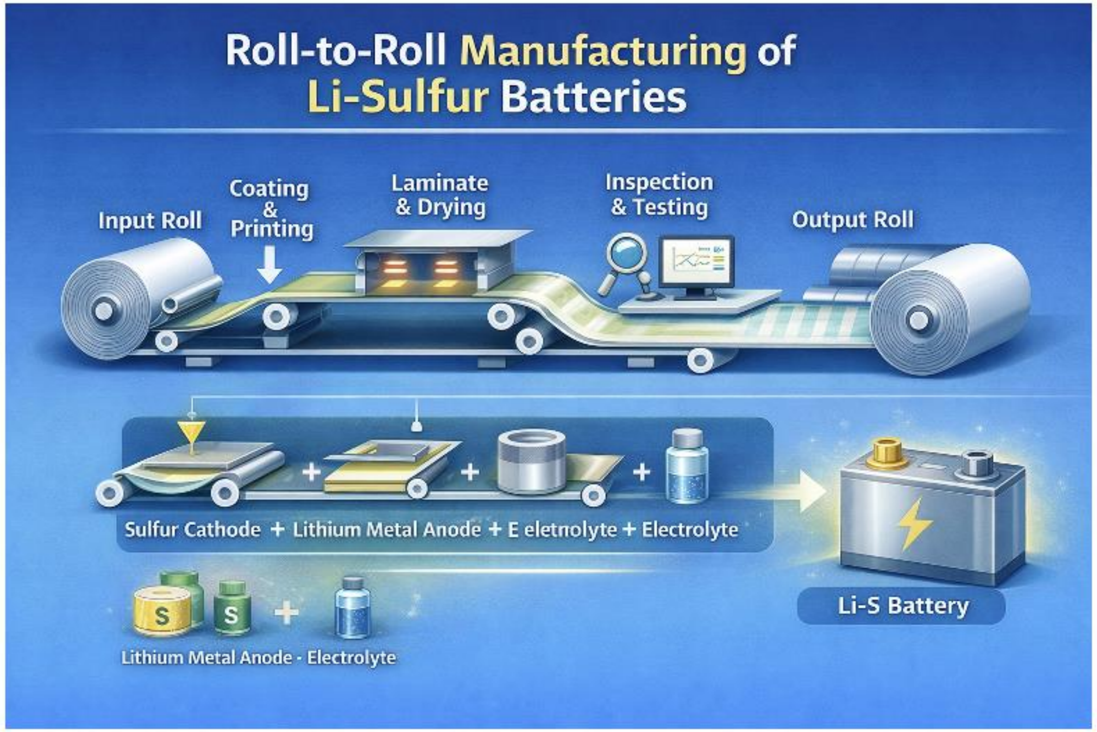
Manufacturing & Scale-up



- Roll-to-roll processing
- ALD/MLD inline integration
- Pouch cell format
- Industrial scalability logic

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Impact

Ambition

- TRL 2 → 4–6
- Industrial relevance
- Battery2030+ contribution
- Future commercialization pathway

Sustainability & Safety

- Reduced critical raw materials
- Sulphur utilization
- Fluorine-free electrolyte pathways
- Safer electrochemistry

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Keep in touch!

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- https://www.linkedin.com/company/angelic-project
- angelic-project.eu

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Magnesium batteries as a key technology for a sustainable energy future

Dr. Yuri Surace

Austrian Institute of Technology

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High-energy, low-cost and scalable generation 5 magnesium-based batteries for mobility applications and beyond

Magnesium batteries: a key technology for a sustainable energy future

Dr. Yuri Surace (AIT - Austrian Institute of Technology)

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Key facts and consortium

HighMag

Duration: 4 years, 01.05.2025 – 30.04.2029

Total Budget: ~5 M€

Consortium: 13 partners from 9 countries

Participant No	Participant short name	Participant organisation name	Country
1. Coordinator	AIT	AIT Austrian Institute of Technology GmbH	AT
2.	UL	University of Limerick	IE
3.	CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives	FR
4.	KIT	Karlsruher Institut für Technologie (Großforschungsaufgabe)	DE
5.	UFr	ALBERT-LUDWIGS-UNIVERSITAET FREIBURG	DE
6.	AMAZ	AMAZEMET Sp. z o. o.	PL
7.	BIU	Bar Ilan University	IL
8.	ZSW	ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG	DE
9.	DCM	Danube Cell Manufacturing GmbH	AT
10.	ICL	IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	UK
11.	LUT	LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO	FI
12.	F6S	F6S Network	IE
13.	PSI	Paul Scherrer Institute	CH

- 5 RTO
- 5 Universities
- 3 Industries & SME

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HighMag's vision and goal

HighMag

- Establish rechargeable magnesium batteries (RMB) as the next-generation energy storage technology.
- Develop RMB with higher energy, lower cost, improved safety and sustainability in comparison to Li-ion batteries.
    - By leveraging the electrochemical properties, abundance and low-cost of magnesium
- HighMag targets mobility applications (EVs and Aeronautics)

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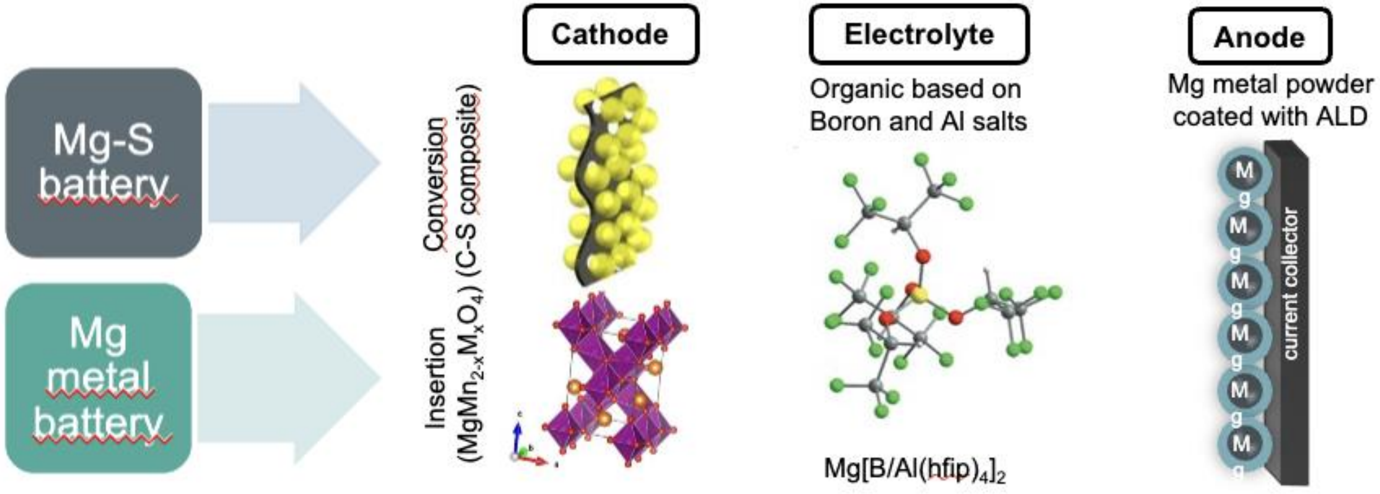
Core Technology

HighMag

Two rechargeable magnesium battery systems (RMBs)

- **Magnesium sulphur battery** with a high-capacity conversion cathode (**Mg-S**)
- **Magnesium metal battery** with a high-voltage insertion cathode (**MMB**)
- Both systems use **Mg-metal powder anode**



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Ref images: https://doi.org/10.1016/j.carbon.2015.03.008, https://doi.org/10.1016/j.ssi.2019.115136, https://doi.org/10.3389/fchem.2018.00656

Core technology – Cell components

HighMag

Carbon-sulphur composites

- Carbons with tunable porosity produced from sustainable precursors
  - Waste plastics (PET, PE) or biomass (grass cuttings, nut shells)
  - Electrocatalysts to improve the kinetics of S conversion

KPI:
>800 mAh/g

$MgMn_{2-x}M_xO_4$ (MMO) spinel

- High throughput screening (HTS) for novel materials discovery
  - Combinatorial magnetron co-sputtering to create thin-film libraries of MMO
- Sustainable and scalable routes to produce MMO powders
  - Transfer promising compositions from thin-film to powders
  - Co-precipitation synthesis to ensure compatibility with Li-ion production processes

KPI:
>200 mAh/g
>3.5 V

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Core technology – Cell components

HighMag

Borate/Aluminate-based electrolytes

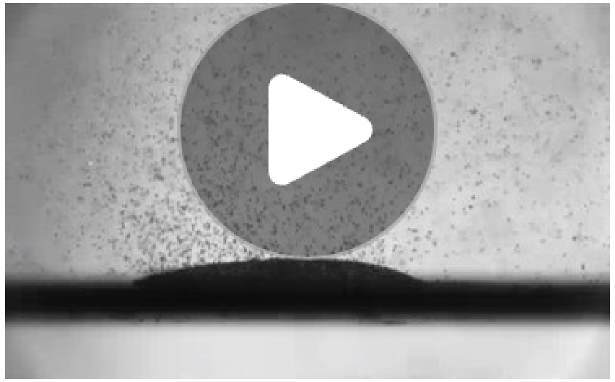
- Baseline $Mg[M(hfip)_4]_2$ (M=B, Al)-based electrolytes
  - Novel electrolyte additives for anode/cathode interphase formation
  - PFAS-free electrolytes

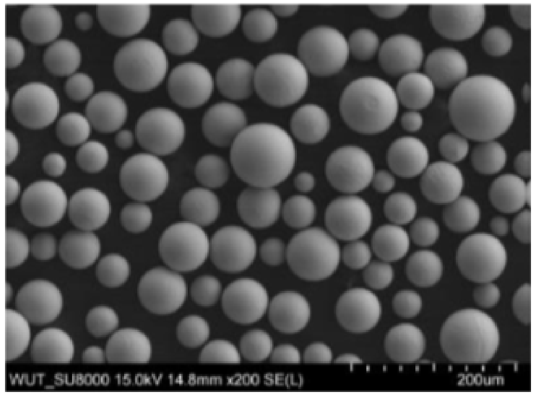
KPI:
>4.0 V
> 99.5% CE

Protected Mg-metal powder anode

- Production via ultrasonic atomization resulting in spherical particles
- Protective surface coatings via ALD
  - Designed for safety, processability, and electrochemical performance

KPI:
>99.5% purity
d90<60µm
<10nm thick coating





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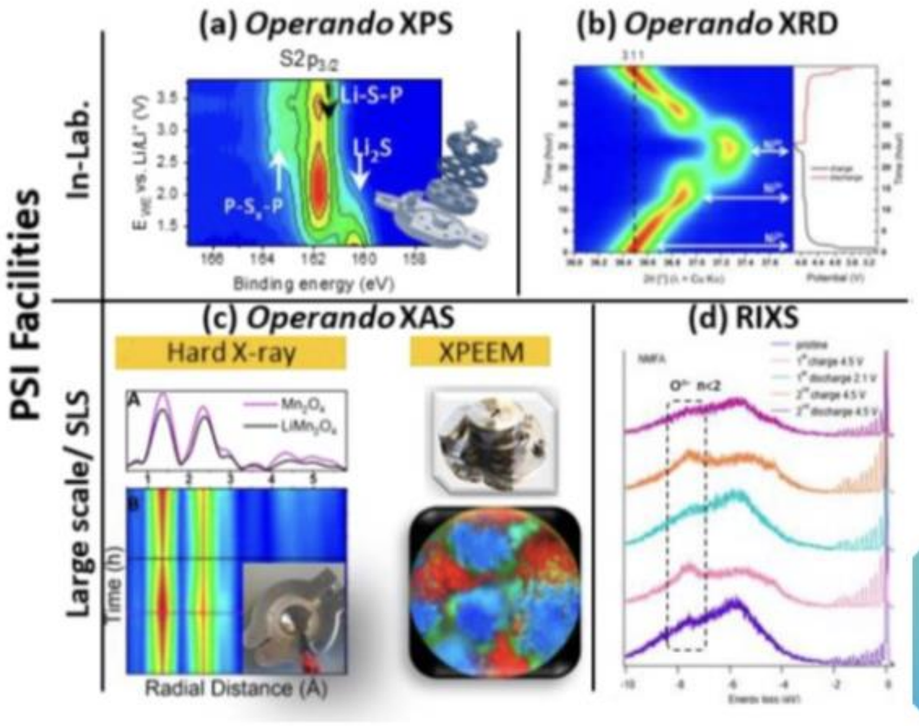
Core technology - Advanced characterization

HighMag

Provide a fundamental understanding of the RMB technology and support materials development

- Surface and bulk analysis
  - Focus on operando techniques
  - Lab-scale and large-scale facilities (e.g. synchrotron)
- Thermal analysis
  - Thermal properties of cell components and their interactions
- Gas analysis
  - Investigation of gas evolving during cycling



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Manufacturing concept

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Validation of the Mg-S and MMB systems at TRL 4 as pouch cell prototypes

- Upscaling aqueous anode and cathode slurries using roll-to-roll process at pilot scale
  - Assessment of manufacturing compatibility with Li-ion infrastructure
- Manufacturing multi-layer pouch cell prototype (1 Ah)
- Electrochemical and safety tests

KPI:
- 500 Wh/kg – 600 Wh/l
- 400 cycles (80%DoD)
- EUCAR<4
- 2 to 10 C rate
- <75€/kWh

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Sustainability & Safety by design

HighMag

- **Safe and sustainable by design and life cycle analysis (LCA)**
- **Techno-economical analysis**
  - Materials value chain
  - Cell production
  - Application (EVs and aviation)
- **Recycling strategies**
  - Development of recycling routes for CRM (Mn, Mg)

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HighMag

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Thank you

VISIT US AT www.highmag-project.eu

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Lithium–Sulphur Batteries: Powering the Future of Safe and Sustainable Mobility

Dr. Ainhoa Fernandez

CIDETEC Energy Storage

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TALISSMAN

Technologies for Advanced LIthium-Sulfur batteries toward Safe and Sustainable Mobility Applications.

Lithium-Sulfur Batteries: Powering the Future of Safe and Sustainable Mobility

Webinar | Generation 5 Batteries for Mobility
30th April 2026

Ainhoa Fernández Tena
cidetec
energy storage

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Vision & positioning

Li-ion batteries dominates current market
High performance
Industrial maturity
Global scalability

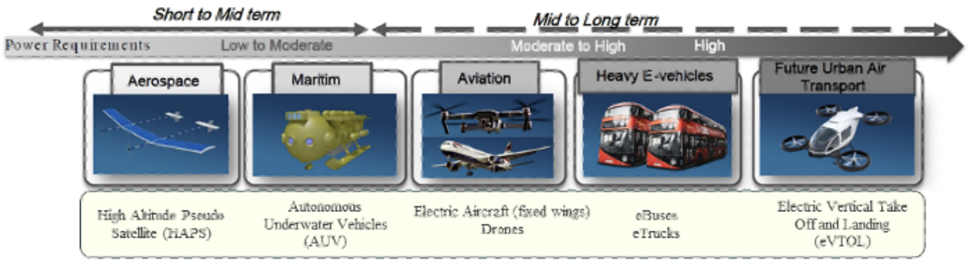
Slow down in Li-ion battery advances
Critical raw materials
Sustainable constraints
Need for higher energy density

Lithium Sulfur technology
great balance
between energy, cost, safety and environmental impact

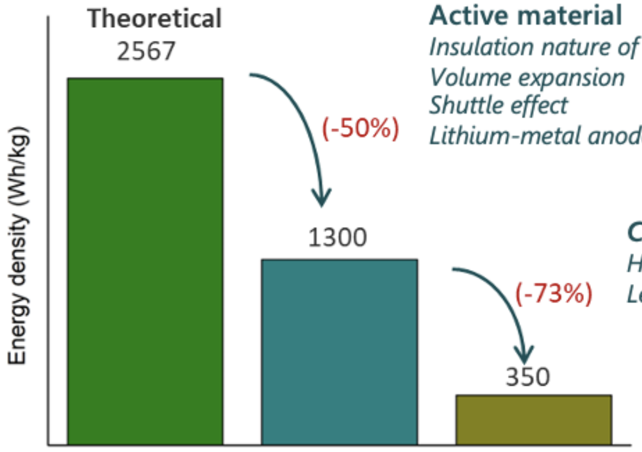
Sulfur: low cost, wide abundance and non-toxic

Ultrahigh theoretical specific capacity (1672 mAh/g) and energy density with lithium metal anode (2600 Wh/kg)

Possible to achieve batteries of 500 Wh/kg



Challenges to overcome in LiS



Active material
Insulation nature of S and its low practical utilization
Volume expansion
Shuttle effect
Lithium-metal anode degradation

Cell level
High sulfur loading cathodes
Lean electrolytes

Scalable manufacturing techniques
Compatible with existing production lines

MADE IN EU

Still hard work to implement LiS technology in European market

Why TALISSMAN

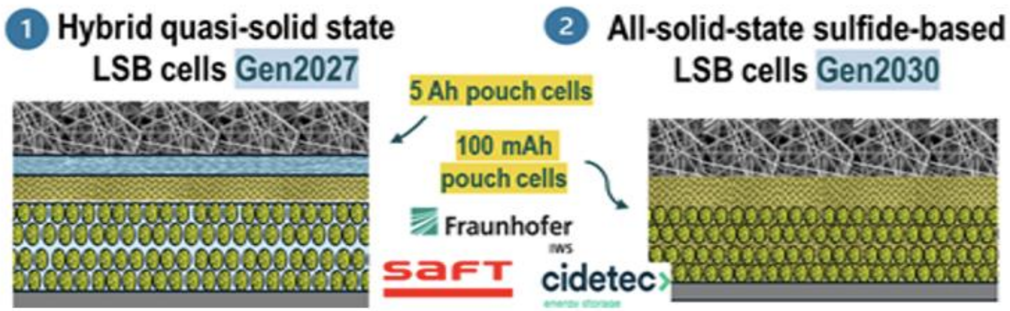
TALISSMAN

Technologies for Advanced Lithium-Sulfur batteries toward Safe and Sustainable Mobility Applications.

TALISSMAN seeks to develop **safe**, **high-performance**, and **sustainable** lithium-sulphur batteries for **aerospace** and **electromobility** applications. By advancing **gelled** and **solid-state battery** concepts, TALISSMAN addresses key technical barriers to industrialisation.

The project integrates **eco-design, circularity, and recyclability principles**, while ensuring **compatibility with existing production lines**. A strong focus on stakeholder engagement and open science will support market uptake and contribute to Europe's battery technology leadership.

- **Call:** HORIZON-CL5-2024-D2-02
- **Grant N°:** 101203047
- 9 partners
- **Led by:** CIDETEC Energy Storage and SAFT
- **Duration:** 48 months (July 2025 – Jun 2029)
- **Current state:** M10 (end first year)

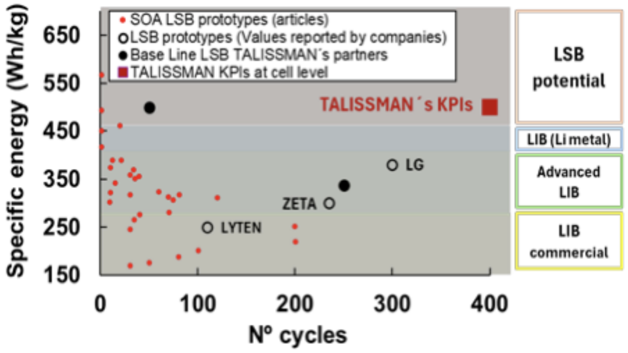


Targeted performance ambitions

IMPACTS

Improved Technical Performance

Energy density vs Nº cycles benchmark for LSB cells



> 500 Wh/kg
> 700 Wh/L
> 400 cycles (80% DoD)
C-rate > 3C

Increased safety

EHL 2-3

Superior Cost-Effectiveness

€75/kWh

SPECIFIC OBJECTIVES

- Safe and efficient 3D lithium-metal anodes.
- Advanced electrolytes for stable performance.
- High-performance sulphur cathodes.
- Understanding and preventing battery degradation process.
- Pilot-scale validation of battery prototypes.
- Sustainability and circularity by design.
- Industrial uptake and exploitation.

Technological approach

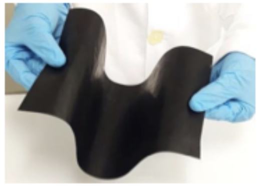
3D Lithium metal anode

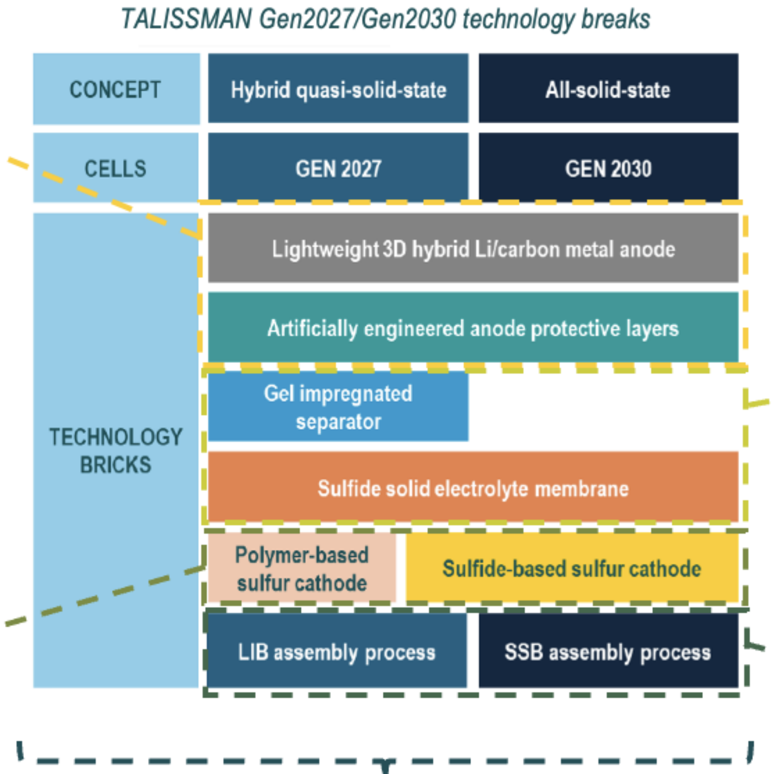
3D carbon-based current collector

Lithiophilicity enhancement

Lithiation

Surface protection





Advanced electrolyte

Gel polymer electrolyte

Advanced liquid electrolyte formulation

Gel polymer electrolyte

Separator benchmarking

Sulfide solid electrolyte membrane

Slurry-based wet processing

Dry-film processing

Sulfur cathode

Polymer-based cathode

C/S composite development

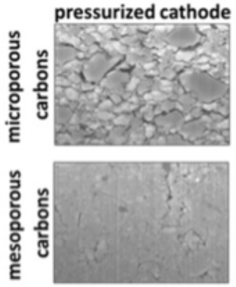
Polymer content <30% and porosity <20%

Water-processable

Sulfide-based cathode

C/S composite development

Wet and dry processing



Cell performance

Electrochemical and safety tests

Cell degradation

Modelling

Cell assembly

Assembly process development

Prototype manufacturing

Manufacturing concept and scaling-up

Cell component development at lab-scale

Anode, cathode and electrolytes

↳ ***Performance validation at coin-cell level***

↳ ***Performance validation in single-layer pouch-cell***

Assembly process development

Cell component scaling-up

Anode: *pilot-line*

Electrolyte
- ***GPE:*** *1 L/batch*
- ***SE membrane:*** *A5 (slurry-based) and A6 (dry) sheet size*

Cathode
- ***C/S compote:*** *1 kg/batch*
- ***Electrodes:*** *polymer-based (pilot line) and sulfide-based (DRYtreac® setup)*

Assembly process scaling-up

Gen2027 (LIB assembly process)

0.5 Ah multi-layer pouch cells → 5 Ah multi-layer pouch cells

Gen2030 (SSB assembly process)

100 mAh multi-layer pouch cells

Pilot line for 3D current collector

Pilot line for polymer-based sulfur cathodes

DRYtreac® setup

Expected sustainability/safety impact

SUSTAINABILITY

Usage of Sulfur

Non-toxic and cheap
Avoid critical raw materials (Ni, Co, Mn, etc.)

3D Li anode

Avoid usage of Cu as current collector
More easily recyclable
Reduce Li usage

Water and dry-processing of electrodes

Eco-design and design-for-recyclability guidelines

Prospective life-cycle assessment (p-LCA)

Novel recycling process concept

SAFETY

Stable quasi-solid and all-solid-state electrolytes

Minimize thermal runaway event

Minimize polysulfide shuttle

Avoid side reactions and instabilities

3D Li anode architecture and protective layer

Promote uniform and dense Li plating
Prevent dendrite formation and thermal runaway

Improve cell assembly

Minimize mechanical stress-induced failures

Novel electrode microstructure and cell swelling models

Safer designs

Strategic ambition

Current state

TRL 2-3
Technology concept formulated
Experimental proof of concept (Cathode)

Goal

TRL 4
Technology validated in lab
Recycling strategy (TRL 3)

Increase TRL

Technology roadmap

TRL 6
Manufacturability and scalability assessment
*From **lab** to **pilot line***

INDUSTRIAL RELEVANCE

RTOs and universities

Increase expertise in battery materials and scalable manufacturing
Stronger and more responsive support to industry

Active material providers ARKEMA

Leverage expertise and portfolio for customized battery solutions

Battery manufactures saft

Solidify expertise in LSB technology
Prepare market entry strategy

End-users AIRBUS

Strengthen knowledge in next-generation LSB

TALISSMAN

Technologies for Advanced LIthium-Sulfur batteries toward Safe and Sustainable Mobility Applications.

Thank you for your attention

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Challenge Blocks

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Materials & Technology Breakthroughs

Dr. Damian Cupid

Austrian Institute of Technology

AUSTRIAN INSTITUTE OF TECHNOLOGY

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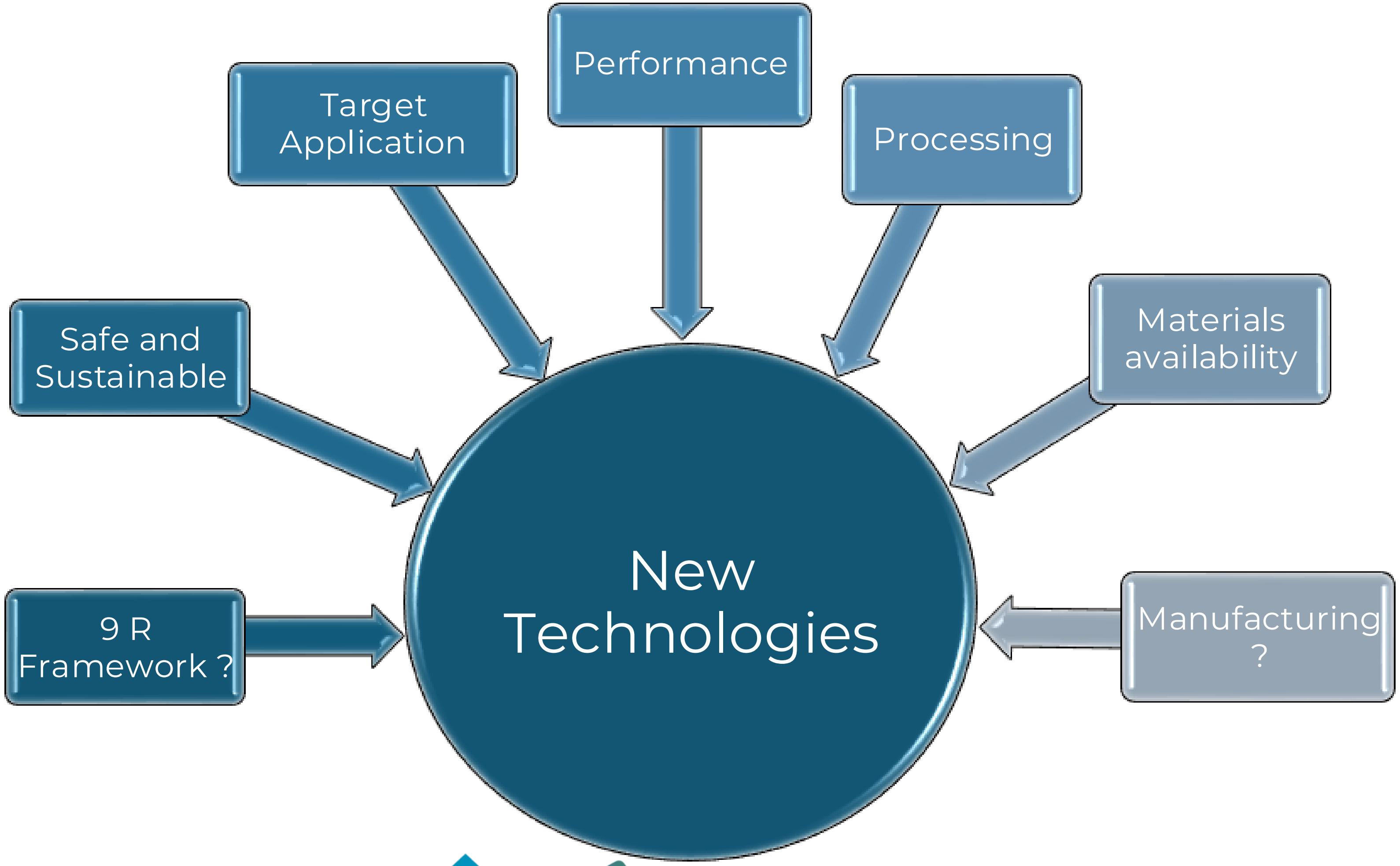
What breakthroughs are needed for technology uptake



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What are the risks?

- TRL Bottlenecks?
- Validation gaps?
- Policies and regulatory frameworks?
- Social acceptance?
- Industrial uptake?

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ANGeLiC

Manufacturing & Industrialisation Readiness

Dr. Didier Devaux

French National Centre for Scientific Research

cnrs

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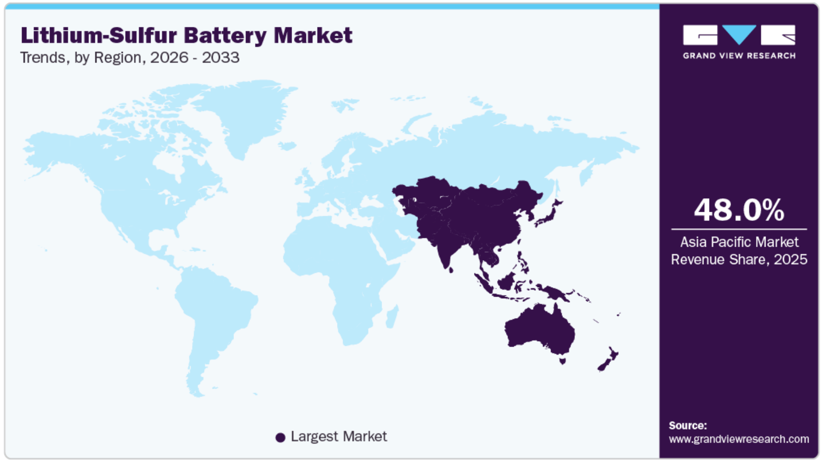
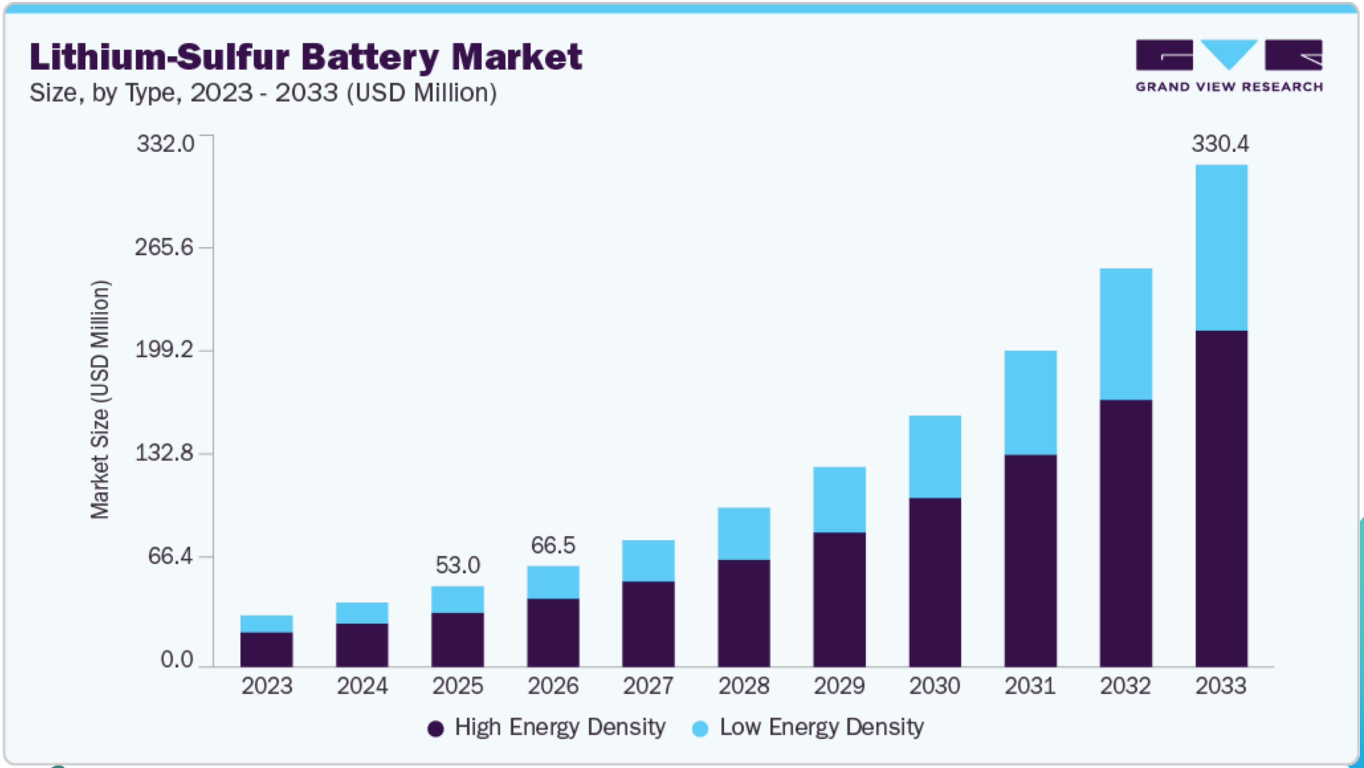
1. Foreseen Li-S Market

- **Rising demand** from aerospace, defense, and advanced mobility sectors is further accelerating market growth.
  ➥ High specific energy and lightweight power sources over long cycle life alone.
  ➥ Align with strengths of Li-S.
- **Increased adoption** in drones, electric aviation concepts, and specialized military systems.
  ➥ Early commercial demand and validate performance in real-world conditions.





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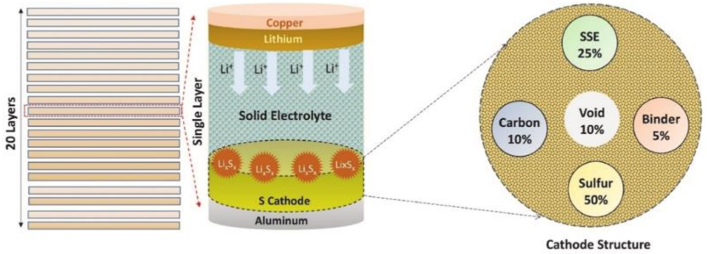
Challenge towards commercialization

- **Pouch cell failure** :
  cathode capacity loss
  ➥ Issues in preparing a uniform slurry, including challenges with density, viscosity, and solid content,
  ➥ Issue with stable electrochemical contact between the active materials.
  ➥ Problematic of Li metal: dendrites, dead Li, passive layers, volume expansion, etc..



	S Cathode	Li Anode	E Electrolyte: Liquid electrolyte	E Electrolyte: Solid electrolyte
Technical Issues	◆ Insulating nature of sulfur ◆ Volume expansion ◆ Instability of polysulfide	◆ Dendrite growth ◆ Solid electrolyte interface ◆ Li-corrosion	◆ Polysulfide shuttle ◆ Inflammability	◆ Low ionic conductivity ◆ Poor Electrode/electrolyte interface ◆ Stability(Mechanical/electrochemical)
Industrial Issues	◆ Low sulfur loading ◆ Low dense cathode structure ◆ High electrolyte utilization ◆ Less sulfur utilization	◆ Internal short circuits ◆ Loss of active material	◆ Inflammability ◆ Low E/S ratio ◆ High Cost	◆ Use of external pressure for contact ◆ Cost of SSE material ◆ Manufacturing of scalable SSE
Solutions	◆ Decrease the particle size ◆ Improving intrinsic conductivity (e.g. seleniumsulfur (Se_xS_y)) ◆ Coating/mixing with conductive agents(e.g. carbon materials)	◆ Ex-situ protective layer (e.g. MoS_2) ◆ Use of Li-alloy as anode (e.g. Li-Al,Li-Mg) ◆ 3D lithium anode structure (e.g. deposition of lithium on CNT structure)	◆ Sparingly Solvating Electrolyte ◆ Highly solvating Electrolyte ◆ Additives engineering (e.g.$LiNO_3$) ◆ Use of solid electrolyte	◆ Use of dual electrolyte (e.g. polymer/inorganic electrolyte) ◆ Stable interface development ◆ Development of thin SSE synthesis

Fig. 5. Technical and industrial challenges for developing Li—S battery and strategical solutions.

Ref: S. Chen *et al.*, SM&T, 45 (2025) e01500

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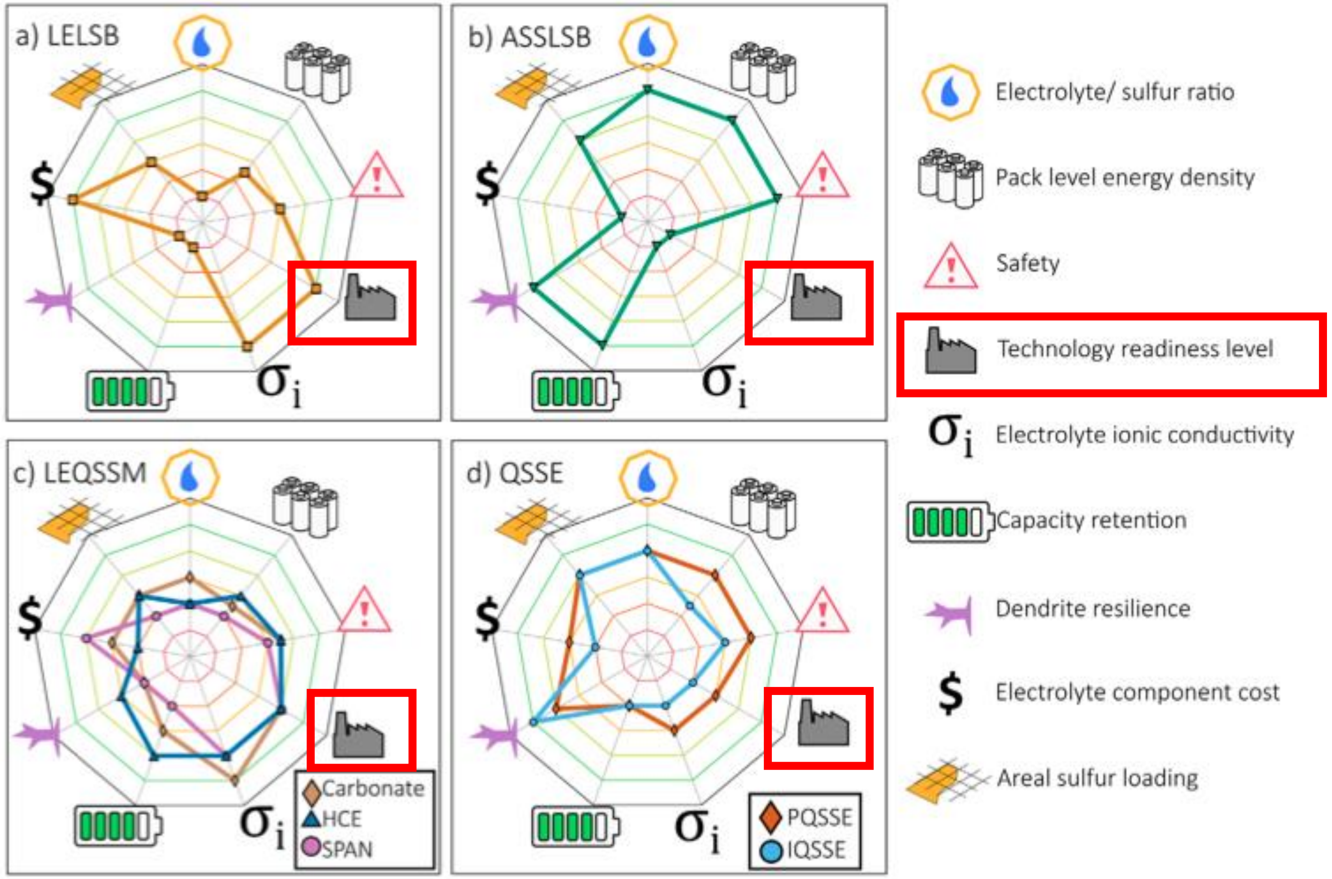
Cell types comparison

- **Radar plots** : advantage and disadvantages of **Li-S electrolyte**
- a) Liquid electrolyte Li-S batteries (*LELSB*),
- b) All solid-state Li-S batteries (*ASSLSB*)
- c) Liquid electrolyte with quasi-solid state conversion mechanism (*LEQSSM*) including cells with carbonate electrolyte, localized highly concentrated electrolyte (*LHCE*) or weakly solvating electrolyte (), and sulfurized polyacrylonitrile (SPA*WSE*N)-based cathodes,
- d) Hybrid solid state electrolyte (*QSSE*) cells with polymer (*PQSSE*) and inorganic (*IQSSE*) electrolytes.



Ref: Y. Shao *et al.*, Adv. Energy Mater., 16 (2026) e03239

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From academia to industry

- **Scientists**
  ➥ very fast and achieved fruitful results in the past decades.

- **Engineer**
  ➥ Commercialization process of Li-S batteries very slow.
  ➥ Market almost Li-S free. The development of Li-S

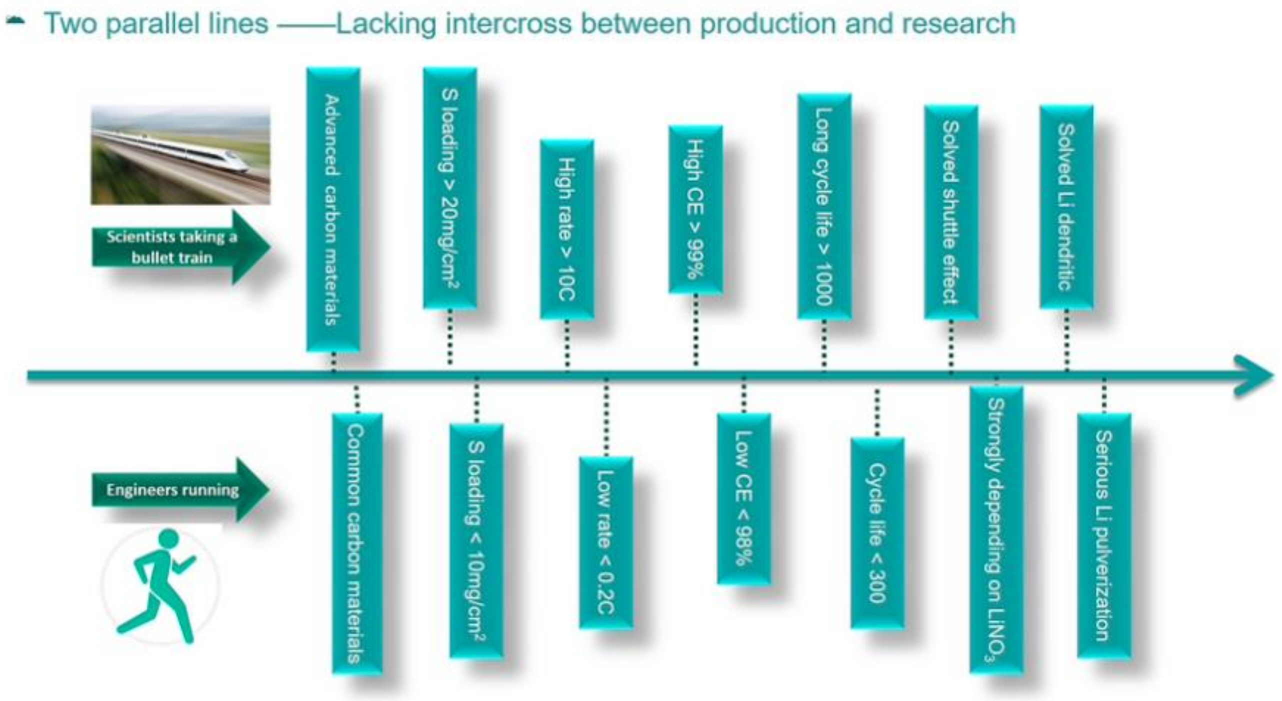

FIGURE 1 | The status of some key factors of academic research and industry production for Li-S batteries.

Ref: K. Zhu et al., Front. Energy Res., 7 (2019) 123.

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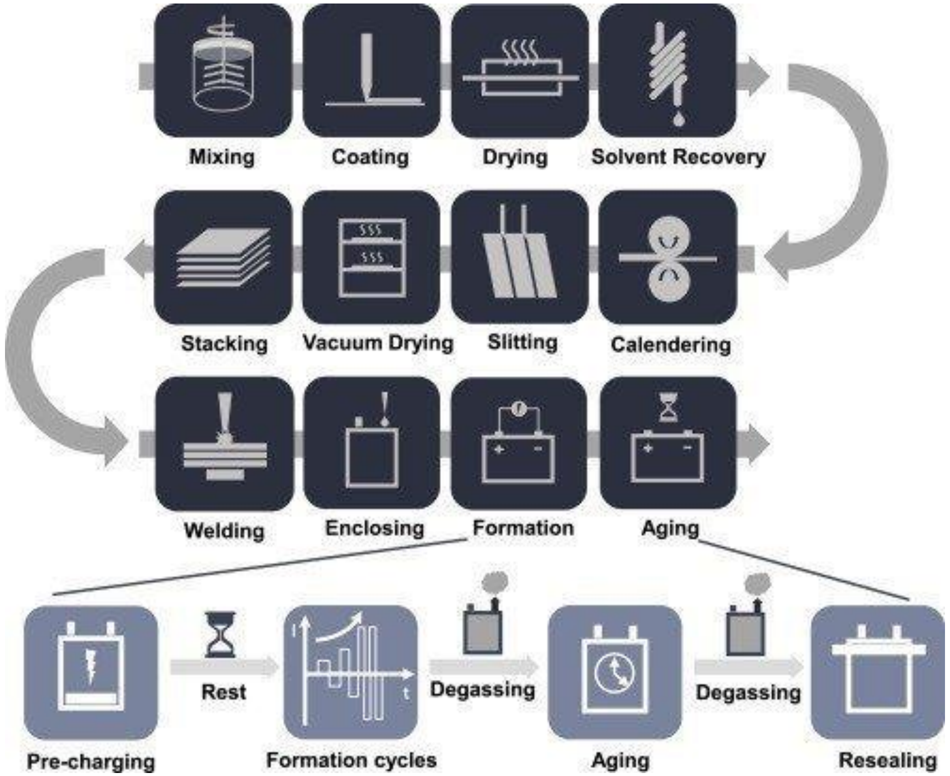
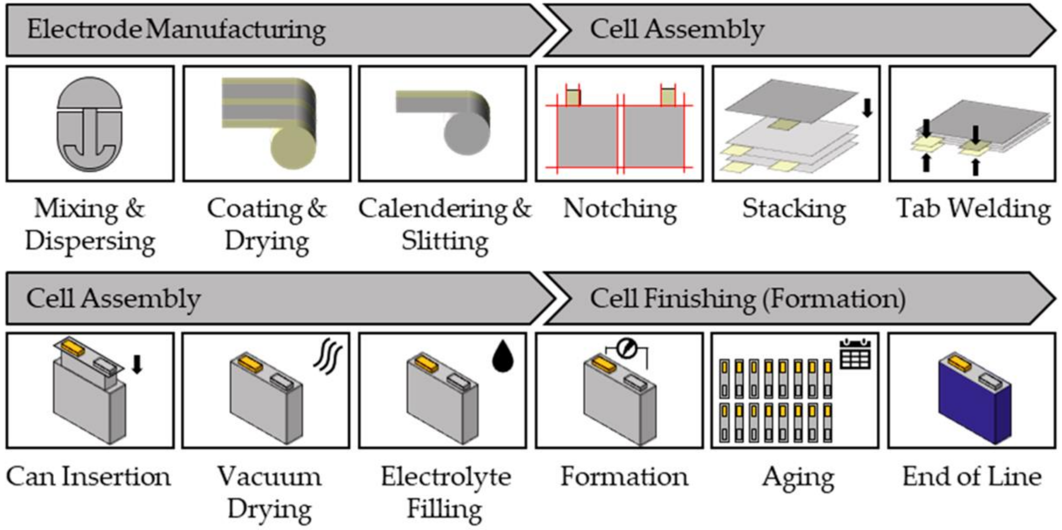
Current manufacturing battery line





- **Main challenge to adapt current battery line with Li-S technologies ?**

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Gen 5 for high energy and high-power applications

Christian Jordy

SAFT

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Introduction

High-power batteries and fast charging for mobility

- Quick charge requirements: ex
  - On road: (EV, bus, trucks) : 1 to 3C
  - Aviation: 1 to 6C (eVTOL, air taxis, auxiliary power unit...)

⇒ Combining high energy and high power

is a high-stakes challenge for mobility applications

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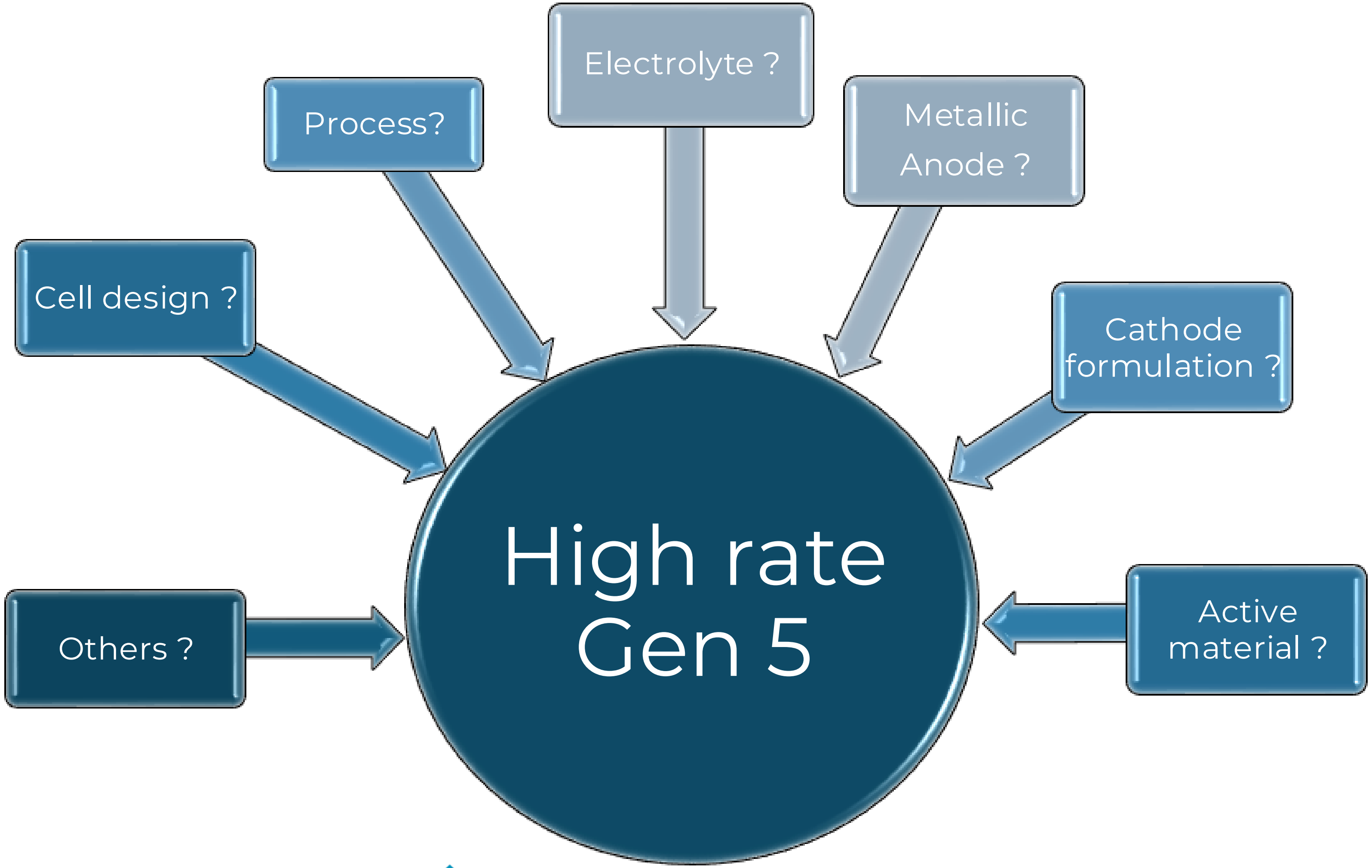
Pain points of Gen5 electrochemistries in delivering fast charging and high-rate discharge capability



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Q&A

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Thank you!

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